

# **The effect of geometric field of view on driving safety and lap times in a racing simulator**

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The goal of this study was to find out if geometric field of view has an effect on driving safety and laptimes in a racing simulator environment. An experiment with 18 participants was carried out in which the participants would drive in a racing simulator with various geometric field of view settings.

Larger geometric field of view seemed to generally give faster average laptimes, but the largest geometric field of view -setting was also the worst setting regarding driving safety. However, either of these findings could not be verified by statistical analysis.

Key words and terms: M.Sc. thesis, field of view, geometric field of view, driving safety, racing simulator, driving simulator.

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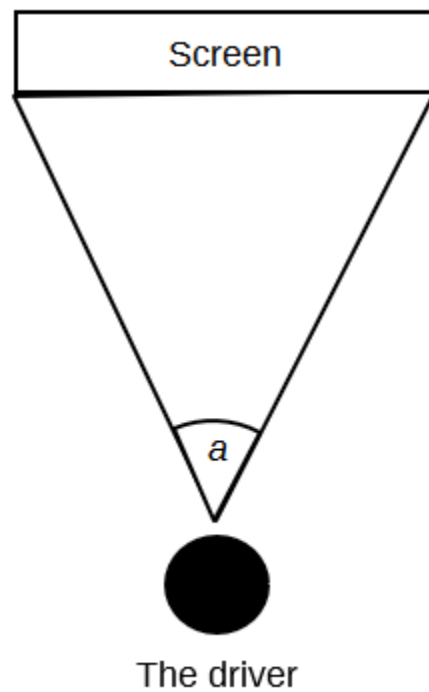
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# 1. Introduction

## 1.1 Basics

Using racing simulator software enables us to learn how to drive a racecar without the need to buy or rent an expensive car and without the need to travel to a race track. You can crash a lot and there is no need for expensive repairs to the car. The same applies to the health of the driver. There will be no broken bones or burn injuries. After an accident, you can just reset the simulation and start again. When the main objective is to simulate driving as realistically as possible to enable drivers to learn real world tracks or the handling characteristics of a certain racecar, we must create an environment realistic and immersive enough so that the driver can take the experience from the simulation and apply it successfully in the real world.

This thesis is about the field of view the driver is presented in such simulations. By field of view I mean the angle the virtual world is seen by the driver. The angle is measured in degrees and can be calculated both vertically and horizontally. In this thesis, when we talk about field of view we mean the horizontal field of view. There are two different kinds of field of view -types that are important to understand: 1) *Projected field of view* (PFOV) and 2) *Geometric field of view* (GFOV). Projected field of view means the horizontal field of view covered by the screen in ones view. In other words, how large portion of ones view the screen covers (see figure 1). The angle of projected field of view depends on the distance between the driver's eyes and the screen and on the width of the screen. There are simulator setups that have more than one screen so we are not limited to using just one screen, but in this thesis we will focus on using only a single screen.



*Figure 1:  $a$  = Projected field of view (PFOV)*

Geometric field of view on the other hand is the virtual field of view displayed on the screen and can be modified inside the simulation software. It does not depend on the size of the screen or on the distance between the driver and the screen. The figures 2 and 3 have been taken from the same spot in the simulator software, but with different geometric field of view settings. As you can see, the virtual view is much more narrow in the picture with 45 degree geometric field of view. You can also see how the cones for example seem to be further away in the picture with 90 degree geometric field of view, even though the virtual car and the driver are at the exactly same spot in both pictures.



Figure 2 - GFOV 45 degrees



Figure 3 - GFOV 90 degrees

I will now define another term called *authentic field of view* (AFOV). Authentic field of view is a state that is achieved when the geometric field of view matches the projected field of view. We can think that when we have achieved the state of authentic field of view, the view you get from the screen is like a window to the virtual world and the distances in the view are in the right proportions when compared to the real world. With an authentic field of view, your screen will only show you the view that fits inside the window. If you move your screen ie. "the window" closer to you or switch to a different sized screen (or to multiple screens), your geometric field of view has to be adjusted accordingly to keep the distances and the proportions in the view correct.

Increasing the geometric field of view is an often used technique to give the user a wider than authentic field of view in situations where the screen is small or the distance to the screen is relatively long. The makers of the simulation software cannot know what the projected field of view will be for each user of the software, so they will program some kind of default setting. Most driving simulation software set the geometric field of view in such way that the driver can see the whole dashboard and the side-mirrors of the car to provide the driver with good visibility. Usually though the projected field of view will be a lot smaller so the geometric field of view does not match the projected field of view or come even close.

The problem with this kind of a situation is that the image will look distorted and the distances in the picture will be skewed if you compare them to the real world. The effect is the same as using a widescreen lens in a camera. Also the sensation of speed has been found to be affected with the geometric field of view settings (Colombet et al. [2011], Mourant et al. [2007], Diels and Parkes [2010] and Richard Goodenough [2010]). If a professional racing driver is using the simulator to learn a racetrack, the distorted view might give him or her a distorted mental picture of the track. So when he or she goes to the same track in the real world it might not appear to be the same at all and that might potentially put the driver in danger.

## 1.2 Background

Even though lots of research has been done regarding driving in simulated environments, the simulated racing aspect seems not to have been researched as much. And racing being a competitive sport, it is possible, that the research done inside the racing teams stays inside the teams in hope to gain an advantage over the other teams. Nevertheless, both civilian and race driving share the same basic principle of driving a car, so it is likely that research done on civilian driving environment can at least partially be applied to the racing environment and vice versa.

Durkee [2010] studied different simulation attributes in his thesis *The effect of simulation attributes on driver perception and behavior*. The participants in the study drove a simulated car and carried out different kinds of speed and distance estimation tasks that were conducted using changing values in multiple parameters including projected field of view. The system used in the study had five forward facing projectors that when combined together created a projected field of view of 240 degrees. There were two projected field of view settings used in the study. The larger view that had the full 240 degrees of projected field of view and a narrower field of view of 55 degrees. The narrow field of view -setting was conducted using only the center projector which created a projected field of view of 55 degrees. The larger field of view -setting on the other hand used all of the projectors. The geometric field of view remained unmodified during the whole test.

Durkee found out in the study, that field of view was a significant parameter when trying to measure the accuracy of perception of speed. Using the larger projected field of view resulted in significantly more accurate results. In the same study the participants also experienced large projected field of view to be significantly more natural than small field of view. It was also observed, that the participants underestimated the speed they were travelling in general (no matter the settings used). The underestimation was bigger with faster



speeds compared to slower speeds. The results are interesting, because the perception of speed is also vital to a racing driver and one could argue that the safety of driving may suffer if the driver constantly is estimating the speed incorrectly.

Colombet et al. [2011] studied the effects of the field of view in a driving simulator by keeping the projected field of view constant (the size of the screen), but modifying the geometric field of view, that is, the field of view of the "virtual camera". They called this ratio between the projected field of view and the geometric field of view as visual scale factor. The participants in the study were given speed reproduction tasks with varying visual scale factor settings. In the experiment, the subjects were given tasks to reproduce speeds of 50km/h and 90km/h without the help of a speedometer. There were five different visual scale factors ( $GFOV / PFOV$ ) between 0.70 and 1.30. A visual scale factor of 1.00 means that the geometric field of view and the projected field of view angles are the same. In other words the field of view is *authentic*.

The results of the study showed that the the perception of speed increases with the visual scale factor. In other words larger geometric field of view values resulted in increased perception of speed. Even a modification of 0.15 in the visual scale factor value the impact was highly significant. In addition, none of the drivers in the study noticed the changes in geometric field of view between the tests. One of the key findings in the study therefore was that it is possible to have drivers drive slower or faster in a simulated environment simply by modifying the geometric field of view.

However, as they also noted, modifying the geometric field of view has an effect on the perception of distances. This is one of the key factors that might become important in my study, because when the goal of the driver is to drive fast around a track, the driver will most probably use the available information of distances to make decisions about when to brake and when to turn in to a corner for example.

Similar findings regarding the relationship between geometric field of view and perception of speed were also presented by Mourant et al. [2007] and Diels and Parkes [2010].

The relationship between geometric field of view and the perception of speed was also verified by Richard Goodenough [2010], but in this study, the visual scale factors larger than 1.69 (1.92 and 2.15 were the tested values) did not give better speed estimation results even though a linear model calculated using the results predicted that the optimal visual scale factor would be 2.59. According to Goodenough, the effectiveness of increasing the visual scale factor may have its limits and also stated that accurate estimation of speed is only one of the important aspects to consider. It is also important to notice, that people have been studied to underestimate the speed they are travelling also in the real world [Recarte & Nunes, 1996; Conchillo et al., 2006].

In addition to perception of speed, there is another field of view -related aspect that has been studied: Collision avoidance. Kaptein, Horst and Hoekstra [1996] studied the effects of field of view and scene complexity on the validity of a fixed-base driving simulator with respect to braking behaviour. In the study, they used two projected field of view settings: 120 degrees (high) and 40 degrees (low). The drivers in the study were presented with a situation where there was a stationary vehicle parked in front of them. The drivers were told to brake as late as possible without causing a collision. The results of the study showed that with the wider projected field of view setting (120 degrees) a smaller safety margin was used and also less accidents occurred compared to the narrower 40 degree view.

### 1.3 This study

Because no earlier research has been done regarding the effects of geometric field of view on driving safety or lap times in a racing simulator, the aim of this study is to provide information on the subject. The research questions for this thesis are following:

1. Does the geometric field of view have an effect on driving safety?
2. Does the geometric field of view have an effect on lap times?
3. Do people notice if the geometric field of view changes between driving sessions?

In search for answers to the research questions presented above, an experiment with 18 participants was carried out. In the experiment, each participant drove three different driving sessions in a racing simulator. In each session, the participant drove around the track for 15 minutes. The simulated car and the track used remained the same during the whole experiment. Between the sessions, only the geometric field of view was modified. The driver was asked to drive as fast as he could, but in a safe way.

## **2. Method**

### **2.1 Participants**

The experiment had 18 participants, ranging from the age of 24 to 43 years. Three of the participants were women and the remaining 15 were men. All of the participants had an active drivers licence. The participants filled out a questionnaire after the driving sessions. In the questionnaire, among other questions (more on those later) there were two questions about prior experience – a question that asked how often did the participant play racing games or simulations and a question that asked how often did the participant go drive on a real racetrack. There were four options to choose from in the questions regarding prior experience: never, rarely, sometimes and often. If we give the different choices points so that never is zero points, rarely is one point, sometimes is two points and often is three points and count the averages on both questions we get an average of 0,667 points on prior experience on racing games and simulations and 0,278 points on prior experience on real world track driving. Those numbers tell us that the participants were rather inexperienced in a competitive driving environment on average.

### **2.2 Procedure and equipment**

Every participant drove one session with geometric field of view of 45 degrees, one session with 55 degrees and one session with 65 degrees. The order of the sessions varied. To minimize the effect of learning, the field of view settings were organized in such way that every combination was run an equal amount of times. Because there are nine different combinations of settings (three sessions and three geometric field of view -settings), each combination was run twice to get 18 test arrangements to match the amount of participants. The size

of the screen and the distance between the screen and the driver remained the same during all of the driving sessions. Therefore the projected field of view was kept at 55 degrees at all times. With this kind of setup one of the sessions was driven with authentic field of view (the session with geometric field of view of 55 degrees) and the other two sessions were driven with settings on both sides of the authentic field of view. Earlier studies by Colombet et al. [2011] and Goodenough et al. [2011] have discovered that people might not notice the modification of geometric field of view, so the participants were not told about the modification of the geometric field of view beforehand. After the driving sessions, the participants were presented with a questionnaire that they would fill. They would fill their age, gender and if they had an active drivers licence. The questionnaire also had a couple of questions about the earlier experience they had in racing games or simulations and on the other hand about the experience they had in real world driving on a racing track. In the end, the participants were asked if they noticed anything different between the sessions and if they did, what did they notice.

The experiment was conducted using the iRacing.com MOTORSPORT SIMULATIONS™ software. The selected car for this experiment was Volkswagen Jetta™ TDI and the track used was the short course version of the Okayama International Circuit™.

The simulator was run with automatic gear help, so that the driver did not have to change the gears. The only controls used by the driver were the steering wheel and the pedals. The driver could use the clutch pedal if he wanted to, but it was not required because the simulation software took care of the gear changes.

The two things measured in the experiment were the amount of driving incidents and the lap times. The driving incidents were situations where any of the following conditions was met:

- the car was off the track
- the driver had lost the control of the car
- there was a contact

### **Off the track**

The track is marked with two white lines that define the borders of the track. If the car has three or more tires outside these lines it is considered to be off the track.

### **Losing control of the car**

If the front end of the car is more than 90 degrees off the direction where the car is moving, then it is considered that the driver has lost the control of the car.

### **Contact**

There is a contact, if the car collides with a wall or another similar solid object.

The iRacing simulator prints out a result sheet that was used to gather the lap times and identify the incidents. However, there is a limitation in the software: It does not register two off track incidents for example if they don't have enough time between them. Because of this, in this study, the actual measured thing is laps with an incident. That could be reliably measured even though it is not the ideal way of doing things.

The other measured thing, lap times, also has something to consider. To get comparable results, the first lap after leaving the pits (the outlap) was not taken in to account. That is simply because the car does not have the time to get

up to speed before the lap timing begins. That will make the outlap several seconds slower than a lap that begins with more speed when crossing the start-finish line. That is why the decision was made not to take the outlap laptimes into account.

### **3. Results**

#### **3.1 Laps with an incident**

The iRacing simulator online service went offline during one of the sessions and therefore we had to end that particular driving session sooner than planned and I could not get the result sheet from that session. That makes 17 successful sessions with driving error and laptimes data.

In total, there were 280 laps with an incident recorded (see Table 1). The combined amount of laps with an incident in sessions with geometric field of view of 45 degrees and geometric field of view of 55 degrees both were 90 laps with an incident each (32%). The total amount of laps with an incident in sessions with geometric field of view of 65 degrees was 100 laps with an incident (36%). The average amount of laps with an incident was 5,29 laps with an incident per driving session with both geometric field of view of 45 degrees and 55 degrees. The average amount of laps with an incident was 5,88 laps with an incident per driving session with geometric field of view of 65 degrees.



<b>Participant</b>	<b>GFOV 45</b>	<b>GFOV 55</b>	<b>GFOV 65</b>
1	11	8	12
2	2	6	8
3	0	0	0
4	4	4	1
5	9	10	13
6	3	5	4
7	8	4	5
8	10	6	2
9	7	5	6
10	4	10	6
11	6	9	10
12	11	11	12
13	0	1	4
14	2	0	1
15	8	9	5
16	0	0	0
17	5	2	11
<b>total</b>	<b>90</b>	<b>90</b>	<b>100</b>
<b>average</b>	<b>5,29</b>	<b>5,29</b>	<b>5,88</b>

*Table 1: laps with an incident per session*

A one-way within subjects (or repeated measures) ANOVA was conducted to compare the effect of geometric field of view setting on the amount of laps with an incident in 45 degrees, 55 degrees and 65 degrees geometric field of view conditions. There was not a significant effect of geometric field of view setting,  $F(2,15) = 0,274$ ,  $p = 0,764$ .

### 3.2 Laptimes

The valid laptimes for each driving session were averaged to get comparable results. The average laptime in a driving session with a geometric field of view setting of 45 degrees was 01:14,358. The average laptime in a driving session with a geometric field of view setting of 55 degrees was 01:13,576. The average laptime in a driving session with a geometric field of view setting of 65 degrees was 01:12,850.

Figure 5 and table 2 show the average lap times per driving session.

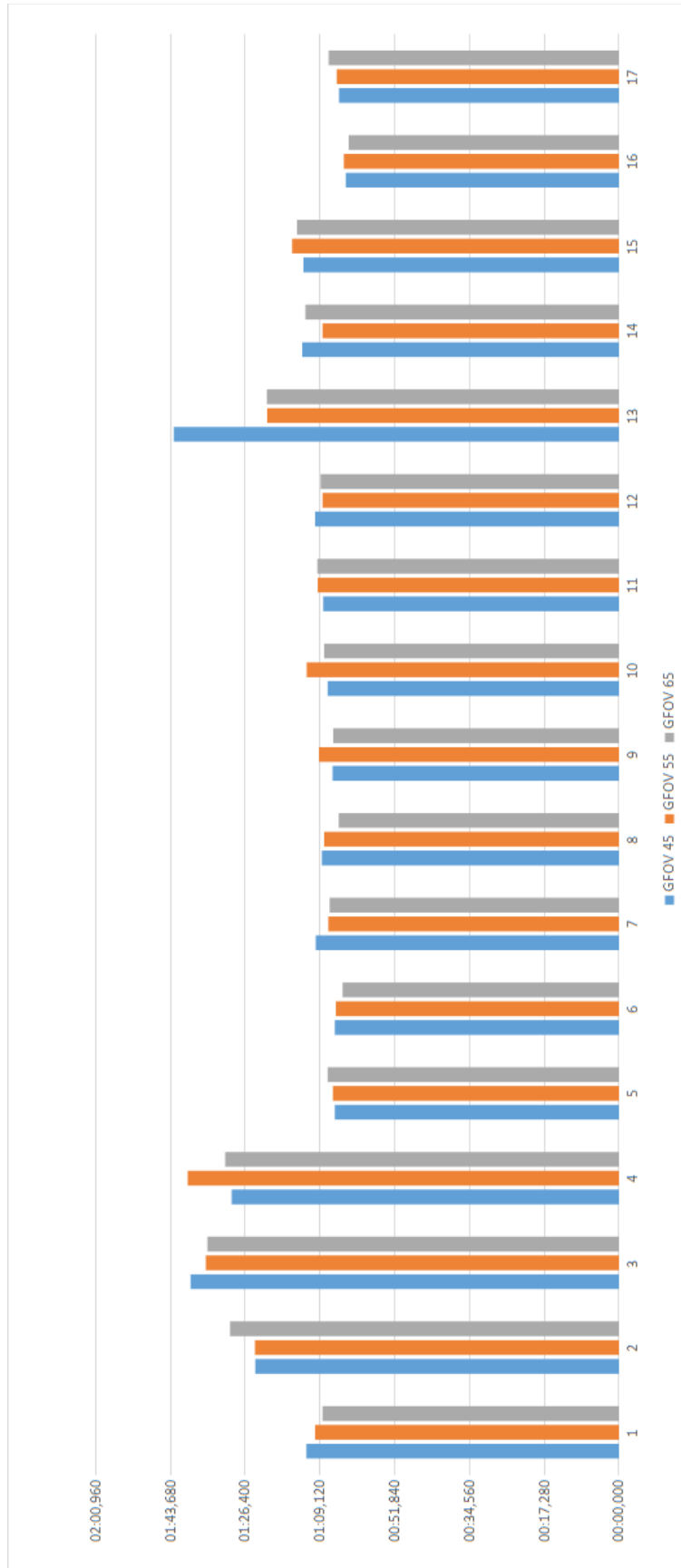


Figure 5: Average lap times

<b>Participant</b>	<b>GFOV 45</b>	<b>GFOV 55</b>	<b>GFOV 65</b>
1	01:12,240	01:10,271	01:08,562
2	01:24,085	01:24,189	01:29,927
3	01:39,015	01:35,506	01:35,134
4	01:29,527	01:39,735	01:31,061
5	01:05,672	01:06,147	01:07,320
6	01:05,654	01:05,455	01:03,902
7	01:10,068	01:07,203	01:06,903
8	01:08,719	01:08,146	01:04,796
9	01:06,229	01:09,388	01:06,039
10	01:07,300	01:12,221	01:08,164
11	01:08,397	01:09,651	01:09,735
12	01:10,225	01:08,573	01:09,017
13	01:42,945	01:21,346	01:21,385
14	01:13,219	01:08,517	01:12,513
15	01:12,954	01:15,595	01:14,407
16	01:03,142	01:03,639	01:02,508
17	01:04,691	01:05,210	01:07,078
<b>average</b>	<b>01:14,358</b>	<b>01:13,576</b>	<b>01:12,850</b>

*Table 2: Average lap times per session*

A one-way within subjects (or repeated measures) ANOVA was conducted to compare the effect of geometric field of view setting on lap times in 45 degrees, 55 degrees and 65 degrees geometric field of view conditions. There was not a significant effect of geometric field of view setting,  $F(2,15) = 0,872$ ,  $p = 0,438$ .

### 3.3 Questionnaire

In the questionnaire, the participants were asked if they noticed any differences in the simulation between the driving sessions. Of the 18 participants, four selected the no-option. 14 participants selected yes. Two of the participants that selected yes described their own performance or behaviour as the only thing that was different between the sessions. So we can say that 12 participants noticed differences in the simulator setting itself.

Of those 12, the differences described by the participants could be categorized in three classes:

Differences in the car behaviour	7
Differences in the view	5
Differences in the force feedback of the car	1

So five of 18 participants (27,8%) noticed that there was something different in the driving view between the sessions.

#### **Comments about differences in the view:**

(the original comments were in finnish, so these are free translations)

*"The field of view was different in the last driving session."*

*"FOV-difference, the field of vision of the driver was different between the sessions."*

*"Different amount of the cabin could be seen in the different sessions. For example the gauges could be seen better in some sessions."*

*"The field of view was different between the sessions in the simulation. The first and the third simulation reminded each other strongly. There was a speedometer showing miles in the upper part of the gauges, which I was concentrating on during the first simulation. In the second simulation there were no gauges, but there was a speedometer showing kilometers in hour in the bottom left corner of the screen. I focused on following the speed in addition to driving lines during the driving. The differences in displaying the speedometer or the gauges made controlling the vehicle harder. In the last simulation the both speedometers were visible. In this situation I followed the km/h-display. Also the visibility during the driving was more narrow during the first and the third simulation which had an "in car"-point of view."*

*"*

*- distance in relation to "real" driving position*

*- brightness? Probably because of what was mentioned above*

*"*

Five of the participants noticed the difference in the view, but even more thought that the differences were in the car. Seven of the participants (38,9%) thought that either the car behaved in a different way or was switched to a whole different car during the experiment.

## 4. Discussion

Results of this study show, that there was no significant effect of geometric field of view of setting on the amount of laps with an incident or on lap times. However, the amount of laps with an incident was the highest with the largest geometric field of view setting of 65 degrees. The distances in the virtual world seem longer with larger geometric field of view so it is possible that people over estimate the amount of space they have when braking into a corner for example. That might lead into situations where they run out of space and go off the track or lose control of the vehicle.

On the other hand though, the average lap times were faster with higher geometric field of view. This might be explained by the fact that with a larger geometric field of view your vision is broader so you can see more to the sides. With a narrow geometric field of view you have kind of a tunnel vision. Same kind of effect like looking through a telescope. Broader view might give you better spatial awareness and when cornering you know earlier when you can start straightening the car and to apply more power. This advantage will most likely diminish when the track becomes more familiar and you start to remember the track and its corners better.

Learning in general is a big factor and that is why the order of the geometric field of view settings were evened out so that it would have a minimal effect on the results. If for example the same geometric field of view setting would be the last one in every experiment, that particular setting might have the least amount of incidents and the best lap times because of learning. It is expected that the participants will learn the track during the experiment and also how the car handles in different situations. They might also be more tense during the first driving session and become more relaxed when they become more familiar with the driving.

There are some other things as well that we have to take into account when looking at the results. For example, the tire temperatures and tire pressures do

not stay the same during the driving sessions. They change constantly when driving and have an effect on the grip of the tires. The same applies to fuel. Driving consumes fuel and that also has a slight effect on the behaviour of the car. So in a way, the participants that wrote that the car changed during the experiment were on to something, because these dynamic variables did change and the car handled differently in various situations. But every time the car was reset to the pitbox, all these values were reset as well and everyone always started with the same parameters as everyone else.

The findings suggest that even though we could get no evidence of significant effect of geometric field of view, in an experiment with more participants there might be a significant effect and further study on the matter is needed.

One of the research questions was that do people notice if the geometric field of view changes between the sessions. In our experiment, the majority did not notice a difference in the view but some did. In this experiment all the tested geometric field of view values were pretty close to each other (45 – 55 – 65), so the results might be different if the changes would have been more dramatic and thus more obvious. All in all, our research did not support the findings by Colombet et al. [2011], where there were none that could spot the difference when they changed the geometric field of view. Even though the majority did not notice the differences, five of 18 participants still did.



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